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(दूसरा पुनरीक्षण)

Glossary of Terms Relating to Iron and Steel

Part 2 Steel Making

(Second Revision)

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FOREWORD

This Indian Standard (Part 2) (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Wrought Steel Products Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard was published in 1962 and subsequently revised in 1976. While reviewing this standard, in the light of experience gained during these years, the Committee decided to revise it to bring in line with the present practices being followed by the Indian industry and corresponding International standards on terminology.

In this revision the following terms have been added:

AOD, Castrip, Continuous Casting, Desiliconization, ESR, Ladle, Ladle Metallurgy, Ladle Metallurgy Furnace (LMF), Lance, Periclase, Quartz, Reduction ratio, Scale, Sequence Casting, Sponge Iron, Tap-to-Tap Time, Thin Slab Casting, Torpedo Ladles, Tuyeres, Vacuum Degassing, Vacuum Oxygen Decarburization (VOD), VAR, Zirconia.

A separate Section 3 covering the classifications of steel has also been added in this revision

This standard is published in seven parts. The other parts in the series are:

Part 1	General metallurgy, heat treatment and testing
Part 3	Long products (including bars, rods, sections and wires)
Part 4	Flat products
Part 6	Forging (including drop forging)
Part 7	Wrought iron
Part 8	Steel tubes and pipes

In formulating this standard assistance has been derived from the following publications:

ISO 6929	Steel products — Definitions and classifications
BS EN 10079	Definitions of steel products

Indian Standard

GLOSSARY OF TERMS RELATING TO IRON AND STEEL

PART 2 STEEL MAKING

(Second Revision)

1 SCOPE

This standard (Part 2) covers definitions of the terms commonly used in the field of steel making and classification of steel.

2 REFERENCE

The standards listed below contain provisions, which through reference in this text constitute provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standard indicated below:

IS No.	*Title*
7598 : 1990	Classification of steels

3 TERMS AND DEFINITIONS

3.1 Acid Bottom — Furnace bottom (that is, hearth) of a melting furnace made of acid refractory such as silica bricks.

3.2 Acid Process — A steel-making process in which steel is refined under an acid slag in an acid refractory lined furnace or converter.

3.3 Acid Refractory — A refractory material, acidic in chemical composition and containing high proportion of silica, that is, silica sand and ganister.

3.4 Acid Steel — Steel made by acid process.

3.5 After Blow — The final stage of refining in the basic Bessemer process in which phosphorus is eliminated.

3.6 Alloying Element — An element (a metal or non-metal) added deliberately to another metal to modify its mechanical and or physical properties.

3.7 Alumina — Aluminium oxide (Al_2O_3), a common constituent of many refractory materials used in steel making.

3.8 AOD (Argon-Oxygen Decarburization) — A secondary steelmaking process in which oxygen and argon are blown into the molten steel to enable carbon to be removed without oxidizing chromium. It is the main method of refining stainless steel (*see also* VOD).

3.9 Arc Process — *See* ‘Electric Arc Process’.

3.10 Basal Crack — A crack in the ingot base caused by restriction to free contraction during solidification.

3.11 Basic Oxygen Furnace (BOF) — Basic oxygen furnace or furnaces is another name, used generally in USA, for LD converters.

3.12 Basic Oxygen Process — Basic Oxygen Process is another name generally used for the LD process and sometimes used to denote basic oxygen processes which include the whole family of steel-making processes carried out in basic lined furnaces where oxygen is used for removing the impurities.

3.13 Basic Process — A steel-making process in which steel is refined under a basic slag in a basic refractory lined furnace or converter.

3.14 Basic Refractory — A refractory material basic in chemical composition, and containing high amounts of oxides such as lime and magnesia, for example, calcined dolomite or magnesite.

3.15 Basic Steel — Steel made by the basic process.

3.16 Bath Sample (Spoon Sample) — A sample taken from molten steel in the furnace, for estimation and analysis of constituents.

3.17 Bessemer Process — A steel-making process in which pig iron is refined in an acid refractory lined converter by blowing air, or mixture of air, carbon dioxide and oxygen or steam through the molten metal. The basic process is known as Thomas process (*see also* ‘Thomas Process’).

3.18 Bessemer Steel — Steel made by the Bessemer process.

3.19 Bleeding — Escape of liquid steel through the bursting of the shell of a partly solidified ingot due to build up of pressure inside the solidifying mass, or escape of liquid from the core of an ingot, withdrawn from the mould before it has solidified sufficiently.

3.20 Blow — In a Bessemer or other converter, one complete cycle of operations.

NOTE — In Bessemer process, a product of a single charge, that is a cast, is also known as a blow.

3.21 Blow Hole (Gas Cavity) — Cavities in solid steel formed by entrapped gas bubbles during solidification.

3.22 Blown Ingot — An ingot with pronounced blow holes.

3.23 Blown Metal — Liquid pig iron which has been subjected to blowing in the converter, as a result of which the iron is refined to the degree depending on requirement. Blown metal is made into steel by addition of elements as required.

3.24 Boil — A particular stage of open-hearth steel-making or puddling of wrought iron corresponding to the evolution of carbon monoxide gas, as a result of which the molten steel bath appears like a boiling liquid.

3.25 Bottom Casting (Trumpet Casting, Uphill Casting) — Simultaneous casting of a number of ingots by pouring the metal into a central refractory-lined tube or trumpet, whence it flows through refractory runners into the bottom of the moulds.

3.26 Bottom Fash (Bottom Flash, Bottom Fin) — A layer of metal in the space between the base of the mould and the bottom plate which is attached to the ingot. Similarly a layer of metal may be formed at the top, in the space between the mould and the refractory lined hot top, the layer of metal formed being called top flash.

3.27 Bottom Fin — *See* 'Bottom Fash'.

3.28 Bottom Flash — *See* 'Bottom Fash'.

3.29 Bottom Plate (Bottom Stool) — A cast iron plate of suitable size, on which the bottom of the mould (which is open at both ends) sits. This plate may be recessed or refractory lined.

3.30 Bottom Shell — *See* 'Bottom Splash'.

3.31 Bottom Splash (Bottom Shell) — The splash of metal solidifying on the bottom portion of a mould, and later engulfed in the rising column of liquid steel, and arises from the impact of the liquid steel on the bottom plate in initial stages of teeming.

3.32 Bottom Stool — *See* 'Bottom Plate'.

3.33 Cast (Heat or Melt) — Usually the product of a single furnace charge. Sometimes the contents of a furnace are tapped into two or more ladles when the product of each ladle may be called a separate cast.

NOTE — In the Bessemer process, a cast is also known as a blow.

3.34 Carbon Steel — An unalloyed steel (*see* IS 7598).

3.35 Capped Steel — It is a rimming steel in which the depth of the rim is controlled by arresting the rimming action, at the appropriate time. The rimming action can be arrested mechanically by putting a heavy steel plate on the top of the surface of the ingot (mechanical capping), or can be stopped by killing by the addition of deoxidizers on the ingot top (chemical capping). The rimming action can also be stopped by spraying water on the top of the ingot (*see also* **3.138**).

3.36 Casting — Pouring or teeming molten metal into moulds. This also refers to metal objects so produced (*see also* 'Teeming').

3.37 Casting Ladle — A refractory lined receptacle in which liquid steel is received from the furnace for teeming purpose.

3.38 Cast Steel — The term is used for steel castings.

3.39 Casting Shrinkage — Contraction of a casting during solidification and subsequent cooling to ambient temperature.

3.40 Castrip — Process to directly cast molten steel into a final shape and thickness without additional hot or cold rolling. This reduces capital investment, energy, and environmental cost.

3.41 Cauliflower Top — Ingot top, characterized by numerous bulges (like a cauliflower) found in semi-killed/rimming steel ingots. This is caused by the bleeding of metal, when it has reached a mushy stage.

3.42 Cementation — Impregnation of high grade wrought iron with carbon for producing blister bar, by heating in contact with charcoal. Cemented bar thus produced is also called blister bar as the surface is covered with blisters. These bars were once used for making crucible steel.

3.43 Charge — The act of loading material into a vessel. For example, iron ore, coke, and limestone are charged into a Blast Furnace a Basic Oxygen Furnace is charged with scrap and hot metal. It is also used for materials charged in a furnace for producing steel.

3.44 Charger — *See* 'Charging Machine'.

3.45 Charging basket — *See* 'Charging Box'.

3.46 Charging Box (Charging basket) — Cast or fabricated steel or cast iron box used for charging material in steel-making furnace. Charging basket is fabricated with a false bottom steel container for charging scrap in electric furnace.

3.47 Charging Machine (Charger) — A ground or overhead travelling machine used for charging scrap in the steel-making furnace such as open hearth.

3.48 Chromite — A neutral refractory which is a double oxide of chromium and iron. The term is also used for a mineral containing chromic oxide and iron oxide.

3.49 Cinder Pot — *See* 'Slag Pot'.

3.50 Clink — A rupture (internal or external) in ingot, bloom, billets, slabs, etc, caused by thermal stresses.

3.51 CLU Process — Creusot Loire (France) and Uddelholm (Sweden) have developed a process of stainless steel manufacture whereby oxygen is introduced through the converter bottom within a peripheral shield of a coolant like steam, carbon dioxide, etc.

3.52 Cold Metal Process — A process of steel-making using wholly cold metal charge.

3.53 Cold Shut (Teeming Arrest) — An ingot or casting defect resulting from interrupted flow or metal during pouring, causing a discontinuity in the skin.

3.54 Continuous Casting — A process in which molten steel is poured into a water-cooled copper mould for gradual solidification as it is drawn down the caster, turning into a solid steel billet, bloom, or slab. Compared to ingot casting, continuous casting has evolved as the preferred method for making semi-finished steel because of much better yield, productivity and cost performance.

3.55 Contraction Cavity — A cavity formed in an ingot as a result of contraction during solidification. Also referred to as shrinkage cavity or pipe usually located in the hot-top region of killed steel (*see also* 'Pipe').

3.56 Converter — The pear shaped refractory lined (acid or basic) vessel in which the pneumatic steel-making processes are carried out. The vessel is mounted suitably for tilting for introducing the liquid metal and taking out the blown metal. The air, oxygen, carbon dioxide, steam or mixture of these, is blown through a detachable bottom, side or top.

3.57 Crack — A discontinuity in a material (*see* 'Basal Crack' and 'Fin Crack').

3.58 Crazing (Surface Crazing) — Markings on ingot or ingot mould surface in the form of a network, in a mosaic pattern giving the appearance of crocodile skin.

3.59 Crucible Process — A steel-making process in which the charge, generally small (roughly 20 to 25 kg), is melted in a crucible for the production of very high quality steel out of contact with fuel. The product, known as crucible steel, is used for making tool steels.

3.60 Crucible Steel — Steel made by the crucible process.

3.61 Dead Steel — Steel which is quiet in the mould after completion of teeming. This steel is fully deoxidized.

3.62 Deoxidation — Reduction of oxygen content of the finished liquid steel by adding deoxidizers in molten steel bath, in ladles or in the mould.

3.63 Deoxidizers — Substance having a high affinity for oxygen used for finishing steel (*see also* 'Ferro-alloy').

3.64 Dephosphorisation — The process of reduction of phosphorus to the desired extent in steel-making processes.

3.65 Deseaming (Scarfing) — The removal of surface defects from ingots or semi-finished products by an oxy-gas flame.

3.66 Desiliconization — Operation that injects a chemical mixture into a ladle full of hot metal to remove silicon prior to its charging into the basic oxygen furnace.

3.67 Desulphurization — The process of reduction of sulphur to the desired extent in steel-making processes.

3.68 Direct Casting (Top Pouring) — Direct pouring of ingots or castings from ladle, that is, without using any refractory reservoir or tundish, in between.

3.69 Discard — Those portions corresponding to the top and bottom of the ingot which are removed to ensure that the remainder of the material is of satisfactory quality. Also defective material produced in rolling or forging, to be cut from one or both ends of the semi-finished or finished product.

3.70 Dolomite — Dolomite is a naturally occurring rock forming mineral with chemical composition of $CaMg(CO_3)_2$. It is used in steelmaking as a slag conditioner, flux and also as a refractory material.

3.71 Double Skin (Curtaining) — A secondary layer of steel on ingot surface, arising from overflow of molten metal from interior to the space between the solidified ingot face and mould wall. It is also formed by splashing.

3.72 Dozzle — A hollow refractory brick preheated to high temperature and used for providing a feeder head for small ingots.

3.73 Dressing — Preparation of mould surfaces to ensure maximum freedom from surface defects. Also refers to cleaning and/or operations such as chipping, deseaming, etc.

3.74 Duplex Process — Steel-making by a combination of two processes, such as Bessemer and open hearth processes or open hearth and electric processes, the popular combination being one using acid Bessemer converter and basic open hearth furnace.

3.75 Electric Arc Process — A process in which heat is generated by striking an arc between the electrodes (usually graphite) or between electrode and the metal for melting and refining of steel. When the arc is between the electrodes, the process is termed as the indirect arc process and when it is between the metal and the electrode, it is termed as the direct arc process.

3.76 Electric Process — A process of steel-making wherein the source of fuel is electrical energy, that is, heat from electric arc or induced eddy currents and the process is termed accordingly as electric arc process or induction process.

3.77 Electric Steel — Steel made by electric process.

3.78 ESR — Electro-Slag Remelting (Also known as EFR, electro-flux remelting) method of producing refined ingots with fewer inclusions and reduced segregation. The process consists of melting a cast or wrought electrode through a molten slag and solidifying in a water cooled copper mould. An electrical current is passed through the electrode and the electrical resistance of the slag which provides the heat to melt the electrode. The resultant ESR ingot is then conventionally hot forged or rolled.

3.79 Faggot — *See* 'Single Shear Steel'.

3.80 Fash (Barr Flash, Top Fash, Top Flash) — Sharp and ragged edges left after shearing or sawing.

3.81 Feeder Head (Hot Top Sink Head) — A refractory lined receptacle placed on the mould top or built into the ingot mould to reduce the shrinkage cavity (pipe) by keeping the metal in liquid state longer at the top. This arrangement confines the shrinkage cavity to the feeder head.

3.82 Ferro-alloy — An alloy of iron and another element or elements, such as, iron and silicon (ferrosilicon), iron and manganese (ferromanganese), iron and chromium (ferrochromium), iron, silicon and manganese (silicon manganese), etc, used for addition to liquid steel for the purpose of deoxidation, or introducing such alloying elements in steel or both.

3.83 Fettling — Repairing the furnace banks and bottom immediately after a heat is tapped.

3.84 Fin (Flash) — Solidified metallic strip projecting out at right angles from ingot surface and is caused by seepage of liquid metal through a longitudinal crack in the mould, or in the mould joint in case of split mould.

3.85 Fin Crack (Longitudinal Crack) — Crack in the ingot associated with the formation of fin and the resulting obstruction during contraction while cooling.

3.86 Finishings — Finishing additions of ferro-alloys, deoxidizers and/or carburizers (for example, coke) which are made to liquid steel, usually in ladle and at times partly in the furnace, so as to bring the liquid steel to the desired specification.

3.87 Fireclay — A refractory material, essentially hydrated aluminium silicate in composition, having a high fusion point used in the manufacture of refractory bricks or mortar.

3.88 Flakes — *See* 'Hair Line Cracks'.

3.89 Flash *See* 'Fin'.

3.90 Flush Slag — The slag which is deliberately taken out or comes out due to controlled boil from any steel-making furnace**.**

3.91 Fluorspar — Naturally occurring calcium fluoride (CaF_2) used as a flux in basic steel making.

3.92 Flux — Materials, such as lime, limestone, fluorspar, etc, added to form a fusible slag and to adjust its fluidity.

3.93 Ganister — A siliceous refractory material used in acid furnace.

3.94 Gas Cavity — *See* 'Blow Hole'.

3.95 Grain Size Control — A control, exercised during steel making, deoxidation and processing for obtaining steel with the desired grain size.

3.96 Graphite — The mineral graphite is one of the crystalline allotropes of carbon. It is used as a source of carbon, as electricity conducting electrode and as an ingredient in refractory material.

3.97 Haematite (Hematite) — Iron oxide, having a composition Fe_2O_3 occurring in nature associated with varying amounts of impurities.

3.98 Hair Line Cracks (Flakes) — Internal ruptures in steel caused by stresses which probably arise from the combination of several factors such as volume changes due to transformation, brittleness due to the presence of hydrogen and the arrangement of the microstructure resulting from hot-working. The size of such ruptures may vary considerably, but they are usually comparatively short in length when viewed on a surface cut at right angles to the plane of defect and are generally so fine that they cannot be discerned other than after etching or by magnetic crack detection. When hairline cracks are exposed by fracturing, they appear as bright crystalline areas of almost circular form, sometimes known as snowflakes.

3.99 Hanger Crack — A transverse ingot crack caused by obstruction to normal contraction of an ingot during cooling in mould and is associated with incorrect feeder head setting. Also occurs from overfilling.

3.100 Heat — *See* 'Cast'.

3.101 Hot Metal Process — A steel-making process using molten metal from blast furnace mixer or cupola as a major portion of the charge.

3.102 Hot Top Sink Head — *See* 'Feeder Head'.

3.103 Inclusions — Particles of oxides, sulphides, silicates, refractories, etc, embedded in the metal.

3.104 Induction Process — A process in which the heating is done by eddy currents generated in the charge by the induction coil surrounding the charge. Depending upon the frequency used, the process is called low frequency, medium frequency and high frequency induction melting.

3.105 Ingot — Castings of suitable shape and size intended for subsequent hot-working.

3.106 Ingot Iron — Very low carbon steel generally made in the open hearth in which all the other elements are removed to the maximum extent possible. Some of the commercial products falling under this group have less than 0.1 percent of all elements put together.

3.107 Ingot Mould (Mould) — The container, usually made of cast iron, into which molten steel is poured and allowed to solidify.

3.108 Ingot Segregation — *See* 'Segregation'.

3.109 Inverse Segregation (Negative Segregation) — *See* 'Segregation'.

3.110 Kaldo Process — A process of steel-making where the impurities are oxidized by blowing high purity oxygen through an inclined lance (or lances) on the surface of high phosphorous molten pig iron held in a basic lined converter which is inclined at about 20° to the horizontal and is rotated at rates up to 35 rev/min.

3.111 Ladle — A 'bucket' shaped container lined with refractory (heat resistant) bricks, used for transporting molten iron or steel from process to process in a steel plant.

3.112 Ladle metallurgy — A process step typically applied in a ladle furnace for alloying, deoxidation, desulphurisation as well as for temperature adjustment prior to casting of quality steels.

3.113 Ladle Metallurgy Furnace/Ladle Furnace (LMF/LF) — An intermediate steel processing unit that further refines the chemistry and controls the temperature of molten steel while it is still in the ladle. The ladle metallurgy step comes after the steel is melted and refined in the electric arc or basic oxygen furnace, but before the steel is sent for casting.

3.114 Ladle Sample — *See* 'Pit Sample'.

3.115 Lance — A long ceramic lined metallic tube through which some gas under high pressure is blown from top into the liquid steel in BOF vessel or ladle. Lance can also be used to inject some Chemicals in powder form to treat the liquid steel.

3.116 LD-A.C. (Arbed Cockerill) Process — This process is an extension of the LD process developed in Belgium wherein lime powder is introduced vertically into an LD converter along with the oxygen in order to make the LD process suitable for refining high phosphorus (up to 2 percent) bearing molten pig iron.

3.117 LD Process (Linz Donawitz Process) — A process of steel-making where the impurities are oxidized by blowing high purity oxygen through a lance at supersonic speeds vertically on the surface of the molten pig iron held in a stationary basic lined converter which itself is kept vertical.

3.118 Lime — A product (calcium oxide, CaO) obtained by burning limestone (calcium carbonate, $CaCO_3$) and is used in basic steel-making practice as a flux and to a limited extent as mould wash.

3.119 Limestone — Naturally occurring calcium carbonate ($CaCO_3$) containing various impurities, chiefly silica and alumina.

3.120 Longitudinal Crack — *See* 'Fin Crack'.

3.121 LWS Process — Developed in France by Creusot Loire, Wendel Sidelor and Establishment Sprunk, the LWS process is identical to the oxygen bottom blown (OBM) process, except that the hydrocarbon shielding agent used is liquid fuel oil instead of the gaseous hydrocarbons used in the OBM process.

3.122 Magnesia — A product (magnesium oxide, MgO) obtained by burning magnesium carbonate ($MgCO_3$) and is used where a high grade basic refractory is desired.

3.123 Magnesite — Naturally occurring magnesium carbonate ($MgCO_3$) containing small amounts of silica, alumina and iron oxide and is used in making banks and bottom of a basic furnace as well as during its fettling.

3.124 Magnetite — The iron oxide, having the composition Fe_3O_4 occurring in nature associated with varying amounts of impurities.

3.125 Melt — A stage in the steel-making process when all the scrap charged has been melted. This term is also synonymous with cast, blow or heat.

3.126 Mixer — A large refractory lined cylindrical or rectangular vessel, provided with tilting arrangement and is used for storage of molten iron and in some cases, for partly refining the stored metal (active mixer used in open hearth shops). Apart from storage, it offers considerable latitude towards the intake of 'off standard' hot iron, and aims in bringing about some uniformity in the supply of hot iron for steel making.

3.127 Mixer Metal — Molten iron from the blast furnace which has been stored in a mixer preparatory to conversion to steel.

3.128 Mould — *See* 'Ingot Mould'.

3.129 Mould Dressing — Materials (such as varnish, lacquer, tar, etc) applied to the inner faces of moulds for better ingot surface.

3.130 Nailing — Slow heating to visible redness of refractory crucibles prior to use of crucibles for the melting of steel.

3.131 Negative Segregation — *See* 'Segregation'.

3.132 Neutral Refractory — A refractory having neither strongly acidic nor basic properties, for example, Chromite.

3.133 Nozzle — The refractory line outlet tube, generally between 25 to 50 mm in diameter, through which molten steel is released from the ladle to fill up moulds.

3.134 Open Hearth Steel — Steel made by the open hearth process.

3.135 Open Hearth Furnace — A furnace having a dish shaped hearth in which the bath is heated by convection from the flame over the surface of the metal and by radiation from the roof. Commonly used for steel making.

3.136 Open Hearth Process — A steel-making process using the open hearth furnace.

3.137 Open Steel — Steel partially killed prior to casting.

3.138 Oxygen Bottom Blown Process (OBM) — Oxygen bottom blown 'Maxhuette' process developed in maxiamillianshuette (South Germany) is a process of steel-making whereby high purity oxygen is introduced through tuyeres at the bottom of a stationary, vertical converter (similar to a Bessemer vessel) which is basic refractory lined. In order to prevent tuyere burning as a result of the intense heat generated during oxidation of the metalloids, the oxygen is blown within peripheral shied of a hydrocarbon gas like propane butane or natural gas which undergoes endothermal cracking at steel-making temperatures.

3.139 Oxygen Lime Powder Process (OLP) — Oxygen lime powder process developed in France is identical to the LD–A.C. process developed in Belgium.

3.140 Plumbago — A material with graphite as the primary constituent, used for its refractoriness.

3.141 Periclase — A natural mineral with the composition of MgO and mainly is used as a major component of most basic refractory bricks.

3.142 Pig Iron — The primary product of smelting iron ore, containing usually about 3 to 4.5 percent carbon along with silicon, manganese, phosphorus and sulphur in varying amounts, depending on the quality of raw materials used. Pig iron is used in the foundry or for conversion into steel.

3.143 Pigging Back — Introduction of carbon in the steel bath by the addition of pig iron.

3.144 Pipe (Contraction Cavity, Shrinkage Cavity) — An axial cavity caused by contraction during solidification of an ingot. Also the defects arising from the axial cavity in the semi-finished or finished products. It may also refer to tubular sections.

3.145 Pit Sample (Ladle Sample) — The sample taken from a cast during teeming into moulds, for determining the chemical composition of the cast.

3.146 Pouring — *See* 'Teeming'.

3.147 Pull — An irregular transverse crack on the face of an ingot caused by restriction to free contraction during cooling in the mould.

3.148 Pyrite — Pyrite has its formula of $FeS_{2.}$ It is used in steelmaking as a source of sulphur.

3.149 Quality Basic Oxygen Process (Q-BOP) — Modified basic oxygen furnace in which the oxygen and other gases are blown in from the bottom, rather than from the top. While the Q-BOP stirs the metal bath more vigorously, allowing for faster processing, the design produces essentially the same steel grades as the top-blowing basic oxygen furnace. Today's state-of-the-art furnace design combines the previous technologies: 60 percent of the oxygen is blown from above, with the rest blown through the bottom of the vessel. This is known as combined blowing process.

3.150 Quartz — A natural mineral having the composition of $SiO_{2.,}$ used in steelmaking to adjust slag basicity and fluidity.

3.151 Rabbling — Stirring or raking the molten steel bath.

3.152 Recarburization — The adjustment of carbon content of molten steel by addition of carbon containing materials.

3.153 Reduction ratio — Typically refers to extent of area compression in the production of hot rolled bar. Reduction ratios of 15:1 used to be the norm for quality applications (for example engineering steels) some years ago, but even this expectation has fallen with the advent of modern continuous casting practices. Lower reduction ratios are currently acceptable for many high quality long product applications

3.154 Reeking — Ingot mould dressing with soot deposition, derived from tar burning.

3.155 Refining — The removal, by slag or other reactions, of undesirable elements and of metallic oxides and gases from molten steel.

3.156 Refining Slag — The finishing slag employed for refining the heat.

3.157 Refractories — Material used in the building and lining of furnaces and capable of withstanding high temperatures under operating conditions, for example, dolomite (double calcium and magnesium carbonate), magnesite (magnesium carbonate), silica (SiO_2), silicates of aluminium, chromic oxides, etc.

3.158 Rephosphorisation — Reversion of or addition of phosphorus into steel under basic steel-making practice.

3.159 Ruhrstahl Heraeus (RH) Processes — The inlet snorkel is equipped with a number of gas injection pipes arranged in the lower section in one or two levels and equally distributed around the circumference. The reaction vessel is designed such that the liquid steel is raised through the inlet snorkel and falls back into the steel ladle after degassing through the outlet snorkel. Top side of the reaction vessel is provided with exhaust, facilities for alloy additions along with observation and control windows. Extremely low final carbon contents of less than 20 ppm can be obtained, as needed for the production of automotive sheets. The addition of alloying elements during degassing has the advantages of achieving higher yields for ferro alloys and high accuracy of chemical analysis of steel due to the absence of air and the avoidance of metal slag reactions.

3.160 Rippled Surface (Wash Marking) — Waviness on ingot surface arising from series of interruptions during casting which cause discontinuities in the rise of steel near the mould walls.

3.161 Rising Steel (Rising Top, Spongy) — A steel, the surface of which continues to rise in the mould after completion of teeming, as a result of vigorous gas evolution during solidification, in view of insufficient deoxidation (that is killing). Solidified steel shows sponginess on the top and often marked internal blow holes.

3.162 Rotor Process — A process of steel-making in which molten iron is refined by oxygen, being characterized by the rotation of the containing vessel or rotor.

3.163 Runner — The refractory channel through which the molten steel enters the mould.

3.164 Scab — The irregular shaped patches of metal or ingot surface arising from cavities in mould walls or caused by loosely adhering layers of metal**.**

3.165 Scale — The oxide of iron that forms on the surface of steel when it is hot.

3.166 Scarfing — *See* ‘Deseaming’.

3.167 Scrap — Iron or steel used for remelting.

3.168 Segregation — A non-uniform distribution, usually a concentration of certain constituents and/or impurities, in a cast product characterized by the mode of solidification of alloys. Segregation usually persists through frequent hot and cold working. Generally, the concentration tends to be higher in the centre than the surface. Sometimes, the reverse of this phenomenon takes place and is known as inverse segregation.

3.169 Sequence casting — Process of casting two or more heats of the same grade of steel in succession through a continuous caster in order to reduce yield losses.

3.170 Shell (Scab, Sliver, Spill) — A relatively thin film or tongue of metal imperfectly attached to the surface of steel. The defect on the sides of the ingot, caused by metal splashed during teeming, having solidified and stuck to mould wall is also called shell or splash.

3.171 Shrinkage Cavity — *See* ‘Pipe’.

3.172 Slag — The covering on the molten metal, of complex oxides formed with the aid of iron oxide (in the form of ore and/or scale) and flux. This non-metallic layer acts as a carrier of oxygen to the molten bath for the oxidation and removal of various elements (such as carbon, silicon, phosphorus, etc) from the molten charge.

3.173 Slag Ladle — *See* ‘Slag Pot’.

3.174 Side Blown Process (Tropenas Process) — A pneumatic process wherein the air or oxygen mixture is injected from the side of the vessel, instead of from the bottom.

3.175 Siemens-Martin Process — It is named after the pioneer work done by Siemens in England and Martin in France, which paved the way for the open hearth steel-making process.

3.176 Siemens-Martin Steel — The steel made by Siemens-Martin process, that is, by open hearth process.

3.177 Silica — Silicon dioxide (SiO_2) occurring in nature as sand and ganister, with varying amounts of other impurities. It is used as an acid refractory.

3.178 Silicate — A compound of silica and a metallic oxide.

3.179 Single Lap — A type of lap occurring due to interruption in teeming.

3.180 Single Shear Steel (Faggot) — A cutlery steel obtained by forging (and welding) a pile of converted bars (termed as a faggot). At times, the forged product is piled by cutting it into pieces and reforged, the resulting product being termed as a double-shear steel.

3.181 Skin Holes — Holes visible on ingot surface.

3.182 Skull — Solidified metal with some amount of slag and refractories remaining in furnace or ladle after the molten metal is poured out. It may also refer to the film formed inside a mould after casting. If detached it may get entrapped and lead to skull patches.

3.183 Skull Patch — A thin layer of solid metal deposited in the inner mould wall and trapped during teeming.

3.184 Slag Inclusion — *See* 'Slag Patch'.

3.185 Slag Pan — *See* 'Slag Pot'.

3.186 Slag Patch (Slag Inclusion) — Slag trapped in the steel during solidification.

3.187 Slag Pot (Slag Ladle, Cinder Pot, Slag Pan) — Cast or fabricated receptacles used for slag disposal.

3.188 Slagging — Taking out molten slag from the furnace.

3.189 Splash — A layer of steel with uneven and rough surface formed over the bottom portion of an ingot and arises from the solidification of the spray of liquid steel reaching the mould wall due to rebound after impact on the bottom plate during early stages of teeming.

3.190 Sponge iron — A metallic product made by direct reduction of iron, via the removal of oxygen from iron ore. Sponge iron is also known as DRI, or direct reduced iron.

3.191 Spoon Sample — *See* 'Bath Sample'.

3.192 Steeling — Charging the raw materials down a steel funnel into the pots used in the crucible process.

3.193 Stock Process — A steel making process utilizing a converter in which pig iron is charged cold and is melted using oil burners introduced through the tuyeres. The charge is then refined by air blast which is side blown.

3.194 Stopper — An arrangement in the ladle tundish which controls the flow of liquid steel to the mould through the nozzle, and consists of a steel rod protected by thick cylindrical refractory sheaths.

3.195 Stripping (Stripper) — The removal of an ingot from a mould after the steel has solidified. The machine used for this purpose is called a stripper.

3.196 Submerged Injection Process (SIP) — Submerged injection process uses the same principle as OBM converters for introducing oxygen in open hearth furnaces. Concentric tuyeres in which the inner tube carries oxygen and the outer tube carries the hydrocarbon shielding agent are inserted below the open hearth bath either through the sides or through the back wall to hasten the rate of refining in open hearth steel making.

3.197 Sub-cutaneous Blow Holes (Sub-surface Blow Holes) — Blow holes just under the surface layer (that is, under the skin) of an ingot, as such they are unoxidized and well up during rolling.

3.198 Talbot Process — A modified basic open hearth steel-making process adopted for phosphoric iron, and is claimed to give greater output and speed. It consists in tapping only a part of the refined steel, from a large tilting furnace, and then adding a fresh charge to fill up the furnace. The resulting charge gets refined quickly, when a portion is tapped out followed by refilling the furnace.

3.199 Tapping — Taking out refined steel from the furnace into a ladle.

3.200 Tap-to-Tap Time — The length of time between successive melting cycles or heats in any steelmaking process.

3.201 Teeming (Casting, Pouring) — Filling of moulds with finished molten steel from the ladle.

3.202 Teeming Arrest — *See* 'Cold Shut'.

3.203 Teeming Lap

a) *Single lap* — A fold in an ingot skin due to the surface of rising steel freezing and forming a rim which adheres to the mould wall and is subsequently engulfed in the ingot surface. Such a fold is more extensive than that described as rippled surface.

b) *Recurrent lap (surging lap)* — A series of single laps which occur mainly in effervescing steel and are caused by an intermittent falling back of the metal level in the mould.

3.204 Temper — A term used to denote the approximate carbon content of carbon tool steels, for example, chisel temper, razor temper, etc. This should not be confused with 'temper' as applied to cold rolled products or to heat treatment.

3.205 Thin Slab Casting — Production of a slab approximately 50 mm - 75 mm thick in a process that is integrated with hot strip casting. The thin slab casting process requires much less gauge reduction of the slab (otherwise undertaken in roughing mills starting with ~250mm thick slab) and the integration with strip rolling means much reduced reheat needs (saving time and energy cost).

3.206 Thomas Process — A basic steel-making process in which pig iron is refined in a basic refractory lined converter by blowing air or a mixture of air, carbon dioxide and oxygen or steam through the molten metal.

3.207 Top Casting (Top Pouring) — Introducing molten steel from the ladle into the mould from top, either directly, or through suitable refractory arrangement (tundish) between the ladle and the mould.

3.208 Top Hat — A deeply sunken top in a rimming steel ingot due to marked gas evolution causing the metal to fall excessively after filling the mould.

3.209 Top Pouring — *See* 'Direct Casting' and 'Top Casting'.

3.210 Topping — Knocking off, by fracturing, the feeder head from a small but tall ingot for examining the fractured surface.

3.211 Torpedo ladles — Huge oval-shaped vessels that transport molten iron to the steelmaking area.

3.212 Tropenas Process — *See* 'Side Blown Process'.

3.213 Trough Castings (Tundish casting) — Casting or pouring effected through a refractory basin or trough, placed between the ladle and the mould, with the object of minimizing the force of impact of the liquid steel on the bottom plate and thus counteract violent splashing resulting from direct teeming from the ladle into the mould.

3.214 Trumpet Casting — *See* 'Bottom Casting'.

3.215 Tundish — The shallow refractory-lined basin on top of the continuous caster. It receives the liquid steel from the ladle, prior to the cast, allowing the operator to precisely regulate the flow of metal into the mold.

3.216 Tundish Casting — *See* 'Trough Castings'.

3.217 Tuyeres — Nozzles arranged in a ring at the bottom of the BOF, through which inert gases are blown into the vessel.

3.218 Uphill Casting — *See* 'Bottom Casting'.

3.219 Vacuum Degassing — A secondary steelmaking operation in which the molten steel is exposed to a vacuum. It results in the removal of gases, particularly hydrogen and usually enables improved cleanness levels to be obtained.

3.220 Vacuum Oxygen Decarburization (VOD) — A ladle steelmaking process for refining stainless steel in which oxygen is injected into molten steel under partial vacuum. This allows carbon to be removed from the steel without oxidising chromium (*see also* AOD).

3.221 VAR -Vacuum Arc Remelting — A method of producing ingots with lower gas content, fewer inclusions and reduced segregation. The process consists of melting a cast or wrought electrode with a DC arc under high vacuum. Molten droplets exposed to the vacuum are collected and solidify to ingot in a water-cooled copper mould.

3.222 Wash Marking—*See* 'Rippled surface'.

3.223 Wild Steel — Steel which reacts violently in the mould due to vigorous liberation of gases during freezing.

3.224 Zirconia — An oxide mineral having formula ZrO_2. Zirconia is used as refractory material.

4 CLASSIFICATION OF STEEL

4.1 Steel

For the purpose of classification, steel is an iron base alloy generally suitable for working to the required shape in the solid state having a carbon content generally less than 1.5 percent and containing varying amounts of other elements. A limited number of high alloyed steels may have more than 2 percent carbon-the usual separator between steel and cast iron (*see* IS 7598).

4.2 Rimming Steel

A steel possessing a rim of purer material (with maximum freedom from surface blemishes), and is associated with evolution of carbon monoxide gas occurring due to the interaction of dissolved iron oxide and carbon during the solidification of low carbon and low manganese steel made under controlled deoxidation. The composition and extent of the rim can be varied and if required, the rimming action can be arrested after sometime (*see also* 'Capped Steel and Plugged Steel').

4.3 Semi-killed Steel

See 'Balanced Steel.'

4.4 Semi-rimmed Steel

See 'Balanced Steel'.

4.5 Balanced Steel (Semi-killed and Semi-rimmed Steel)

Steel to which controlled amounts of deoxidizers have been added in the liquid stage during tapping and teeming, the object being to reduce the severity of piping. This steel is intermediate between killed and rimming types.

4.6 Capped Steel

It is a rimming steel in which the depth of the rim is controlled by arresting the rimming action, at the appropriate time. The rimming action can be arrested mechanically by putting a heavy steel plate on the top of the surface of the ingot (mechanical capping), or can be stopped by killing by the addition of deoxidizers on the ingot top (chemical capping). The rimming action can also be stopped by spraying water on the top of the ingot.

4.7 Killed Steel (Solid Steel)

Steel which has been fully deoxidized to reduce the oxygen content of the steel to a minimum in order that no reaction takes place between carbon and oxygen during solidification.

4.8 Carbon Steel (Unalloyed Steel)

Unalloyed steels are those steels in which specified content of any element is less than that indicated in IS 7598.

4.9 Low-carbon Steels

Low-carbon steels are unalloyed steels containing up to 0.30 percent carbon.

4.10 Medium-carbon Steels

Medium-carbon steels are unalloyed steels containing carbon between 0.30 to 0.60 percent.

4.11 High-carbon Steels

High-carbon steels are unalloyed steels containing carbon more than 0.60 percent.

4.12 Alloy Steel

A steel containing one or more alloying elements as a result of which it develops specific characteristics (*see* IS 7598).

4.13 Low Alloy Steels

Low alloy steels are steels in which total alloying elements are up to and including 5 percent.

4.14 Medium Alloy Steels

Medium alloy steels are steels in which total alloying elements are more than 5 but up to and including 10 percent.

4.15 High Alloy Steels

High alloy steels are steels in which total alloying elements are more than 10 percent.

4.16 Plugged Steel

It is rimming steel poured in a bottle shaped mould with a central plug. The rimming action is arrested when the metal rises and comes in contact with the bottle portion of the mould and the central plug.

4.17 Special Steel

Steel in the production of which special care has to be taken so as to attain the desired cleanliness, surface quality mechanical properties.

4.18 High-Strength Low-Alloy Steels

High-strength low-alloy (HSLA) steels, or microalloyed steels, are designed to provide better mechanical properties and/or greater resistance to atmospheric corrosion than conventional carbon steels in the normal sense because they are designed to meet specific mechanical properties rather than a chemical composition. The HSLA steels have low carbon contents (0.05-0.25 percent C) in order to produce adequate formability and weldability, and they have manganese contents up to 2.0 percent. Small quantities of chromium, nickel, molybdenum, copper, nitrogen, vanadium, niobium, titanium and zirconium are used in various combinations to impart the desired properties.

4.19 Electrical Steel

A group of steels (silicon or aluminum alloyed) used for the construction of magnetic cores of electrical equipment, because of their low watt-loss properties.

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